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CHEMICAL BIOLOGICAL CENTER

U.S. ARMY SOLDIER AND BIOLOGICAL CHEMICAL COMMAND

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**DOMESTIC PREPAREDNESS PROGRAM:
TESTING OF THE VAPORTRACER
AGAINST CHEMICAL WARFARE AGENTS
SUMMARY REPORT**

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RESEARCH AND TECHNOLOGY DIRECTORATE

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PREFACE

The work described in this report was authorized under the Expert Assistance (Equipment Test) Program for the U.S. Army Soldier and Biological Chemical Command (SBCCOM) Program Director for Domestic Preparedness. This work was started in November 2000 and completed in September 2001.

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DOMESTIC PREPAREDNESS PROGRAM: TESTING OF THE VAPORTRACER AGAINST CHEMICAL WARFARE AGENTS SUMMARY REPORT

1. INTRODUCTION

The Department of Defense (DOD) formed the Domestic Preparedness (DP) Program in 1996 in response to Public Law 104-201. One of the objectives is to enhance federal, state, and local capabilities to respond to Nuclear, Biological, and Chemical (NBC) terrorism incidents. Emergency responders who encounter either a contaminated or a potentially contaminated area must survey the area for the presence of either toxic or explosive vapors. Presently, the vapor detectors commonly used are not designed to detect and identify chemical warfare (CW) agents. Little data are available concerning the capability of the commonly used and commercially available detection devices to detect CW agents. Under the DP Expert Assistance (Test Equipment) Program, the U.S. Army Soldier and Biological Chemical Command (SBCCOM) established a program to address this need. The Applied Chemistry Team (ACT), Research and Technology Directorate, U.S. Army Edgewood Chemical Biological Center (ECBC), Aberdeen Proving Ground, MD, performed the detector testing. ACT is tasked with providing the necessary information to aid authorities in selecting detection equipment applicable to their needs.

Reports of the instrument evaluations are posted in the Homeland Defense website (<http://hld.sbccom.army.mil/>) for public access. Instruments evaluated and reported in 1998, 1999, and 2000 include the following:

- MiniRAE plus from RAE Systems, Incorporated (Sunnyvale, CA)
- Passport II Organic Vapor Monitor from Mine Safety Appliances Company (Pittsburgh, PA)
- PI-101 Trace Gas Analyzer from HNU Systems, Incorporated (Newton, MA)
- TVA 1000B Toxic Vapor Analyzer (PID and FID) from Foxboro Company (Foxboro, MA)
- Draeger Colorimetric Tubes (Thioether and Phosphoric Acid Ester) from Draeger Safety, Incorporated (Pittsburgh, PA)
- Photovac MicroFID detector from Perkin-Elmer Corporation (Wellesley, MA)
- MIRAN SapphIRe Air Analyzer from Foxboro Company (Foxboro, MA)
- MSA Colorimetric Tubes (HD and Phosphoric Acid Ester) from Mine Safety Appliances Company (Pittsburgh, PA)
- M90-D1-C Chemical Warfare Detector from Environics OY, Finland
- APD2000 Detectors from Environmental Technologies Group, Incorporated (Baltimore MD)
- SAW MiniCAD mkII from Microsensor Systems, Incorporated (Apopka, FL)
- UC AP2C Monitor from Proengin, Incorporated, France

- ppbRAE Photo-Ionization Detector from RAE Systems, Incorporated (Sunnyvale, CA)
- SABRE2000 detector from Barringer Technologies, Incorporated (Warren, NJ)
- CAM (Type L) from Graseby Dynamics Ltd., United Kingdom

In 2001, the evaluation of instruments continued using test items that were loaned to the DP program by the respective manufacturers. Viable candidate instruments were required to pass a pre-screening test. In exchange, the instruments were evaluated under the DP protocol, and the manufacturers were permitted to take data during the evaluations. Instruments evaluated included the following:

- VaporTracer System from Ion Track Instruments, Incorporated (Wilmington, MA)
- HAZMATCAD from Microsensor Systems, a Sawtek Company (Apopka, FL)
- GC-MS/FPD with Dynatherm System from Agilent (Columbia, MD)
- Scentoscreen GC from Sentex Systems, Incorporated (Fairfield, NJ)

Each of these evaluations will be reported separately. This report pertains to the evaluation of the VaporTracer from Ion Track Instruments, Incorporated.

2. OBJECTIVE

The objective of this report is to assess the capability and general characteristics of the Ion Track Instruments VaporTracer System to detect CW agent vapors. The intent is to provide the emergency responders concerned with CW agent detection an overview of the detection capabilities of the instrument.

3. SCOPE

This evaluation is an attempt to characterize the CW agent detection capability of the VaporTracer System. Due to time and resource limitations, the agents used were limited to tabun (GA), sarin (GB), and mustard (HD). These were chosen as representative CW agents because they are believed to be the most likely threats. Test procedures follow the established DP Detector Test and Evaluation Protocol described in the Phase 1 Test Report.¹ The test concept was as follows:

- Determine the minimum detectable level (MDL) where repeatable detection readings are achieved for each selected CW agent. The current military Joint Services Operational Requirements (JSOR)² served as a guide for detection sensitivity objectives.
- Investigate the effects of humidity and temperature on instrument performance.

- Observe the effects of potential interfering substances upon instrument performance in the laboratory and in the field.

4. EQUIPMENT AND TEST PROCEDURES

4.1 Detector Description.

Ion Track Instruments, Incorporated (ITI), (<http://www.iontrack.com>), is the manufacturer of the VaporTracer System. Two units were loaned to the DP Program for inclusion in the 2001 detector evaluations and randomly labeled A and B. According to the User's Manual,³ the VaporTracer System uses the company's patented Ion Trap Mobility Spectrometry (ITMS) technology to gain increased efficiency and sensitivity over conventional Ion Mobility Spectrometry (IMS).

The instrument is pre-set by the manufacturer with the appropriate system parameters for the CW agent, drugs, or explosives of interest. Additional substances can be added to the list of detectable substances by technically qualified operators. For this evaluation, the VaporTracer units were pre-programmed by the manufacturer to detect and identify several CW agents. Modifications to the instrument were required (e.g., re-setting the timing and IMS cell temperatures) to enable CW agent detection. These changes to the instrument make it a different version from the conventional VaporTracer units used for narcotics and explosives detections.

The manufacturer describes the VaporTracer units evaluated as stand-alone, handheld, portable detection instruments that can sample, detect, and identify vapor and particulate CW agents, explosives, and narcotics. The instrument weighs 9 lb (4.05 kg), and its length is approximately 17 in. (43.2 cm). Figure 1 shows the VaporTracer with the main components labeled. By pressing the "START" button located on the handle, a sample is collected through the sample inlet nozzle and analyzed. The unit displays a bar graph response on the LCD along with a numerical value relative to the alarm level setting and an audible alarm when any programmed substance is detected.

The keypad on the unit is used to step through menus and make selections of functions and operating features such as alarm level and sample time settings, instrument visual and audio adjustments, calibration, and diagnostics and plasmagram (graphic IMS spectrum) displays. When coupled with the optional remote laptop computer, more detailed analytical information and diagnostics functions can be displayed. The laptop connection port is shown in Figure 2.

The patented ITMS involves ionizing sampled vapors that are drawn into the VaporTracer instrument through the nozzle by the sampling pump. The vapor samples flow over a semi-permeable, elastomeric pre-concentrating membrane designed to exclude inorganic compounds such as dust and dirt while allowing target vapors to permeate through the membrane.

The target vapors are carried on a stream of clean, dry air through the Ni-63 foil-lined ionization chamber where positive and negative ions are formed. The pulsed electric field of the VaporTracer forces the ionized sample to proceed to the collector electrode. The speed (ion mobility) at which the ions move toward the collector electrode depends on the mass, size, and shape of the ions. Since ion mobility is very specific for an individual chemical compound, measuring the unique mobility of the target ions in an electric field allows substance identification.

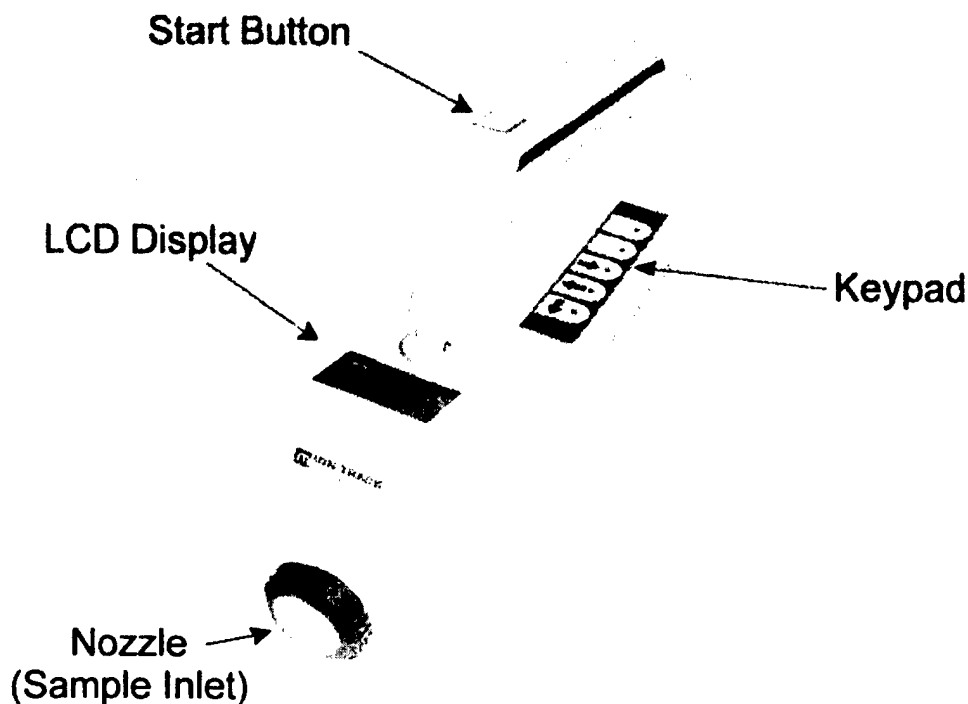


Figure 1. VaporTracer

The manufacturer uses an internal dopant vapor in the gas stream entering the VaporTracer to eliminate interference from the unwanted organic vapor ions from the air. In the absence of the detectable CW agents, either contraband substances or other substances that have stronger ionic charge affinity, the dopant vapor collects those charges from unwanted ions to yield a plasmagram with a single response peak in the spectrum. In the presence of either CW agent, contraband vapors or those substances that have stronger ionic charge affinity, the charge is "stolen" back from the internal dopant ions to form the detection peaks. The dopant tubes are located at the rear of the instrument as shown in Figure 2. According to the manufacturer, the dopant should be checked regularly during weekly maintenance and replaced when necessary.

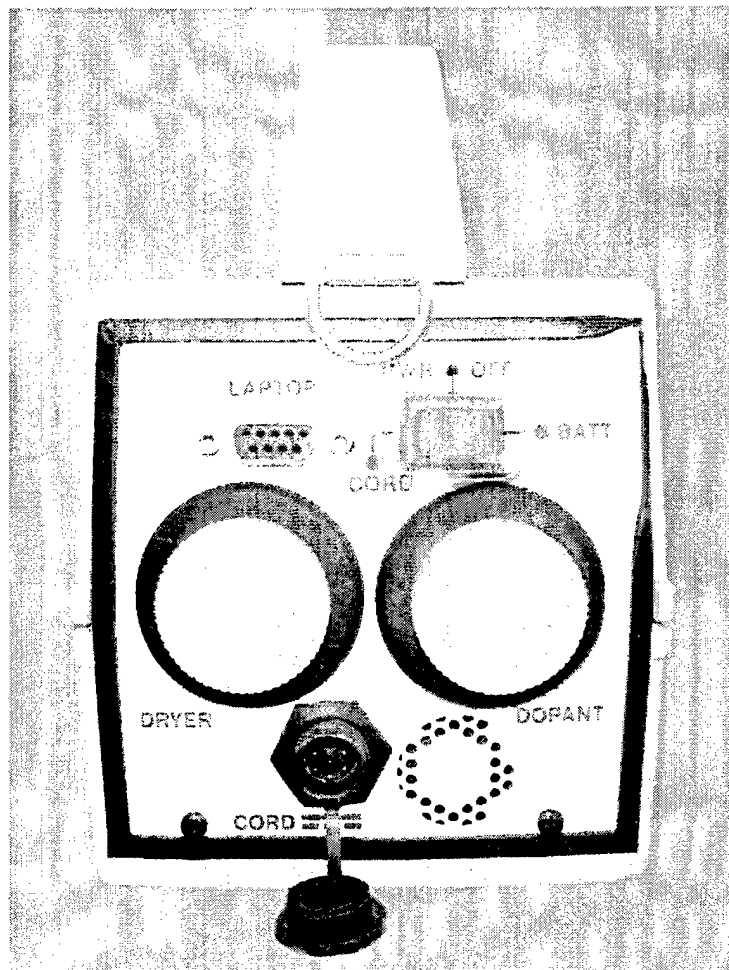


Figure 2. VaporTracer Rear View

The system computer digitally converts the analog data from the detector to allow analysis and identification from these matching pre-programmed substances. The VaporTracer's patented ITMS reduces the background significantly, which permits low-level detection responses and yields significant improvement over conventional IMS.

The instrument is not capable of providing simultaneous detection of blister (HD) and nerve agents. The VaporTracer operates in either its positive or negative ion detection mode. Switching modes requires a physical module change. The appropriate detection mode module, also known as the "BRICK," must be installed prior to powering on the unit to detect the respective substances of interest. The "BRICK" is tightened in place using two setscrews. The positive ionization mode "BRICK" has been programmed to detect GA, GB, GD, and GF (different G nerve agents). The negative ionization mode has been programmed to detect HD (sulfur mustard).

The "START" button must be pressed to initiate each sample collection. According to the manufacturer, the sample is analyzed automatically in approximately 4-10 s, and the results are displayed on the LCD. When a selected substance is detected, an audible alarm sounds, and a bar graph is visually displayed on the LCD along with a numerical value for the response that is relative to the alarm level setting. Using the menu keypad, the units can be pre-set to continue sampling and analyzing for a specific amount of time. For these evaluations, the total sample and analysis cycle time of the unit was set to 90 s.

After a sample is collected and analyzed, the unit either shows the alarm response or shows "READY" for the next sample on its LCD panel. If there is an alarm response, the user can choose to either save the file or to clear the instrument for the next sample cycle. By pressing the "START" button again, the system automatically cycles and continues monitoring itself until clear (no alarm response). After the unit produces three consecutive "CLEAR" analysis cycles, the LCD shows "READY," and then another sample can be collected.

The VaporTracer can operate using 110/220 V 50/60 Hz. It draws approximately 30 W up to a maximum of 65 W during its warm-up period. It can also be operated on its optional 12 V DC batteries. The 12 V DC power can be supplied through either an automotive cigarette lighter adaptor or a belt mounted remote battery pack with power cord. The "POWER ON" switch with its options ("CORD" or "BATT") is shown in Figure 2. These three options require the unit to be powered on in the "CORD" position. The belt battery pack can provide up to 6 hr of operation. Another optional 90 min attachable battery pack can be used when powered on in the "BATT" battery position. The AC power was used during this evaluation to minimize potential battery effects.

The manufacturer recommends that the "POWER ON" switch be in either the "BATT" or "CORD" position (Figure 2) as much as possible, or at least 40 min, to eliminate potential contamination and to permit optimal detection capability.

After operating in high humidity environments, the air purification dryer requires replacement. The dryer material is located in a tube at the rear of the instrument (Figure 2) and removes moisture from the sample airflow prior to the air entering the sensor cell. Moisture entering the IMS cell will significantly affect the proper functioning of the detector. The dryer material should either be changed regularly during weekly maintenance or replaced whenever necessary (e.g., when the unit fails calibration verification). Proper precautions should be exercised when changing the expended dryer material that possibly contains contaminations from sampling.

4.2 Calibration

User's Manual calibration procedures were followed. Calibration procedures differ depending on the selected detection mode (positive or negative). Detection performance was verified daily using either the "INTERNAL CALIBRANT" procedures for negative mode operation, or the "EXTERNAL CALIBRANT" procedures for positive mode operation. The internal calibration process involves following the calibration procedures as directed by the unit's display while in the negative mode, labeled "CAL ON INTERNAL." The external calibration

process, shown on the unit's display as "CAL ON SUBST," requires using the confidence check sample (simulant) provided with the instrument and following the external calibration procedures.

The calibration procedure verifies the known internal and external calibrants by recognizing their peaks in the plasmagram. These peaks may shift slightly with change in atmospheric pressure and/or the effectiveness of the dryer. The instrument self-adjusts the positions of all its known peaks of detectable substances to compensate for the current conditions. The User's Manual states that calibration is required either daily or when there is a change in altitude. After the unit shows "CAL IS DONE," and the results of the calibration are as expected, the "ENTER" button must be pressed. The calibration is saved, and the system will automatically self clear to "READY" mode. Then, sampling and analysis can begin.

4.3 Agent Vapor Challenge.

The agent challenges were conducted using either the Multi-Purpose Chemical Agent Vapor Generation System⁴ using Chemical Agent Standard Analytical Reference Material (CASARM) grade or the highest purity CW agents available. Agent challenge followed successful instrument warm up and confidence check. The vapor generator system permits testing of the instrument with humidity and temperature-conditioned air without agent vapor before challenging it with similarly conditioned air containing the CW agent vapor. This is to assure that the background air does not interfere with the instrument.

The VaporTracer sample inlet nozzle was placed under the cup-like sampling port of the vapor generator and exposed to the conditioned air to establish a stable background before agent challenges. Agent challenge begins when the solenoids of the vapor generation system are energized to switch the air streams from conditioned air only to similarly conditioned air containing the agent. The "START" button is pressed to initiate the sample and analysis cycle, and the VaporTracer immediately begins to collect a sample on the pre-concentrated membrane located at the front of the unit. The time that the detector was exposed to the agent vapor until it first alarmed was recorded as the response time. The time required for the instrument to clear back to "READY" after the sample run was noted as the recovery time.

The instruments were each tested with the agents GA, GB, and HD at several concentration levels at ambient temperatures (18-24 °C) and 50% RH to determine the MDL with each agent. The instruments were then tested at the determined MDL concentrations, ambient temperatures, and both <10% and >90% RH conditions to observe potential humidity effects. Each unit was tested three times under each condition.

The VaporTracer manual does not state a temperature range for the instrument. The effects of low temperature were assessed by testing at -10 °C for GA and GB, and 0 °C for HD. The effects of high temperatures were assessed by testing at +50 °C for GA, GB, and HD. Although HD freezes at approximately +15 °C, the calculated HD volatility of 92 mg/m³ at 0 °C easily produces a vapor concentration higher than the 2 mg/m³ JSOR detection criteria allowing the instrument to be evaluated against HD down to 0 °C.

4.4 Agent Vapor Quantification.

The generated agent vapor concentrations were analyzed independently and reported in the data tables. The vapor concentration was quantified by using the manual sample collection methodology⁵ using the Miniature Continuous Air Monitoring System (MINICAMS[®]) manufactured by O. I. Analytical, Incorporated (Birmingham, AL). The MINICAMS[®] is equipped with a flame photometric detector (FPD), and was operated in either phosphorus mode for the GA and GB agents or sulfur mode for HD.

This system normally monitors air by collection through sample lines and subsequently adsorbing the CW agent onto the solid sorbent contained in a glass tube referred to as the pre-concentrator tube (PCT). The PCT is located after the MINICAMS[®] inlet. The concentrated sample is periodically heat desorbed into a gas chromatographic capillary column for subsequent separation, identification, and quantification. For manual sample collection, the PCT was removed from the MINICAMS[®] during the sampling cycle and connected to a measured suction source to draw the vapor sample from the agent generator. The PCT was then re-inserted into the MINICAMS[®] for analysis. This "manual sample collection" methodology eliminated potential loss of sample along the sampling lines and the inlet assembly when the MINICAMS[®] was used as an analytical instrument. The calibration of the MINICAMS[®] was performed daily using the appropriate standards for the agent of interest. The measured mass equivalent (derived from the MINICAMS chromatogram) divided by the total volume (flow rate multiplied by time) of the vapor sample drawn through the PCT produced the sample concentration that converts into milligrams/cubic meter.

4.5 Field Interference Tests.

The instruments were tested outdoors in the presence of common potential interferents [e.g., vapors from gasoline, diesel fuel, jet propulsion fuel (JP8), kerosene, Aqueous Film Forming Foam (AFFF, used for fire fighting), household chlorine bleach, and insect repellent]. Vapor from a 10% calcium hypochlorite solution (HTH slurry, a chlorinating decontaminant for CW agents), engine exhausts, burning fuels, and other burning materials were also tested. The objective was to assess the ability of the instruments to withstand outdoor environments and to resist false alarm responses when exposed to the selected substances. In these tests, no CW agent was present.

The field tests were conducted outdoors at M-Field, Edgewood Area, Aberdeen Proving Ground, MD, in July 2001. These experiments involved open containers, truck engines, and fire-producing smoke plumes, which were sampled by the detectors at various distances downwind. The VaporTracer units were exposed to either the smoke or fume test plume to achieve moderate concentrations (e.g., 2-15 ft for vapor fumes and 6-30 ft for smokes).

Confidence checks were performed on each unit at the beginning of each testing day and periodically between tests. When possible, the two units were exposed to each interferent for approximately 2 min for three trials. The units were tested in the 90 s sample mode. So, after the "START" button was activated, the detector sampled the interferent for 90 s.

Unit A was in H (negative mode), and Unit B was in G (positive mode). Testing continued with the next challenge after the instruments were thoroughly recovered from prior exposure indicated by "READY" on the LCD.

4.6 Laboratory Interference Tests.

The laboratory interference tests were designed to assess the effect on the detectors of vapor exposure from potential interfering substances. The substances were chosen based on the likelihood of their presence during an emergency response by first responders. Additionally, the laboratory interference tests were conducted to assess the CW agent detection capability in the presence of these interferent vapors.

The VaporTracer units were tested against 1% of the headspace concentrations of gasoline, JP8, diesel fuel, household chlorine bleach, floor wax, AFFF, Spray 9 cleaner, Windex, toluene, and vinegar vapors. They were also tested against 25 ppm NH_3 (ammonia). If the detector false alarmed at 1% concentration, it was tested at the 0.1% concentration of the substance.

To generate the respective vapor concentrations, a dry air stream carried the headspace vapor of the substance by either sweeping it over the liquid in a tube or through the liquid in a bubbler to prepare the interferent gas mixture. For example, 30 mL/min or 3 mL/min of this vapor saturated air diluted to 3 L/min with the conditioned air at ambient temperatures (20-22 °C) and 50-51% RH produce either the 1% or 0.1% concentration of interferent test mixture, respectively. The 25-ppm ammonia was derived by proper dilution of a stream from an analyzed 1% NH_3 vapor (10,000 ppm) compressed gas cylinder diluted with the appropriate amount of the conditioned air.

For the tests that included CW agent, the interferent test gas mixture was prepared similarly. The resultant stream of 3 L/min of HD vapor was used as a dilution stream to blend in with the appropriate 30 or 3 mL/min of the substance vapor flow to obtain the desired 1 or 0.1% mixture of the substance vapor in the presence of CW agent concentration. The two units were tested three times with each combination of agent plus interferent, when possible.

5. RESULTS AND DISCUSSION

5.1 Minimum Detectable Levels.

The MDL with corresponding response times for the VaporTracer units tested are shown (Table 1) for each agent at ambient temperatures and 50% RH. The MDL values represent the lowest CW agent concentration where identification of the CW agents occurred consistently for three trials. Concentrations are shown in milligrams per cubic meter (mg/m^3) and parts-per-million (ppm) units. For comparison, the current military JSOR requirements for CW agent sensitivity for point detection alarms, the U.S. Army's established values for immediate danger to life or health (IDLH), and the airborne exposure limit (AEL) are also listed in Table 1.

Army Regulation (AR) 385-61 is the source for the IDLH and AEL values for GA and GB, and the AEL value for HD. The AR 385-61 does not establish an IDLH for HD due to concerns over carcinogenicity.

Table 1. Minimum Detectable Level (MDL) and Average Response Times at Ambient Temperatures and 50% RH for the VaporTracer

AGENT	Concentration (mg/m ³) with ppm values in parentheses and Response Times			
	VaporTracer MDL	JSOR*	IDLH**	AEL***
HD	0.16 (0.02) in 9-14 s	2.0 (0.300) in 120 s	N/A	0.003 (0.0005) up to 8 hr
GA	0.004 (0.001) in 62-99 s 0.10 (0.015) in 12-20 s	0.1 (0.015) in 30 s	0.2 (0.03) up to 30 min	0.0001 (0.000015) up to 8 hr
GB	0.009 (0.002) in 86-101 s 0.13 (0.02) in 8-18 s	0.1 (0.017) in 30 s	0.2 (0.03) up to 30 min	0.0001 (0.000017) up to 8 hr

*JSOR for detectors.

**IDLH values from AR 385-61, February 1997, to determine level of CW protection.

Personnel must wear either the full ensemble with SCBA for operations or full-face piece respirator for escape.

***AEL values from AR 385-61 to determine masking requirements.

Personnel can operate for up to 8 hr unmasked.

The VaporTracer units detected HD at 0.16 mg/m³ in <15 s, which is an order of magnitude better than the JSOR requirement. The units detected GA and GB in <20 s at the approximate JSOR and IDLH levels. The MDL for nerve agents, GA and GB, were also detected at much lower concentrations than the current military requirements within 2 min of exposure. The GA and GB were consistently detected at 0.004 and 0.009 mg/m³, respectively, in response times between 62 and 101 s. The units were unable to detect the AEL levels for either GA, GB, or HD.

5.2

Temperature and Humidity Effects.

Tables 2, 3, and 4 show the results of the VaporTracer evaluation under various test conditions for agents HD, GA, and GB, respectively. Tests were conducted at ambient temperatures and approximately <10, 50, and 90% RH. The VaporTracer manual does not state an operational temperature range for their instrument, and the manufacturer was unsure of temperature effects. Therefore, an attempt was made to test the instruments at temperature extremes of -10, 0, +40, and +50 °C.

The concentrations used to determine the temperature and humidity effects were based on the previously determined MDLs. Positive detection response is defined as three consistent responses in three independent trials for the agent at the temperature and RH so specified for both VaporTracer units. An entry of NR (No Response) means there was not a positive detection response for both units. The range of numeric response values that are relative to the alarm setting, along with the corresponding range of response times for the two VaporTracer units is given in each table. The numeric response values are seen to increase, as expected, with increasing agent concentration.

Table 2 shows that the VaporTracer consistently demonstrated HD detection only at ambient temperature at the lower RH levels (<90%). Recovery times for HD exposure, except at high concentrations, were <30 s. At high concentrations, the units required up to 125 s for recovery. It appears that temperature and high RH had adverse effects on HD detection, resulting in no response at either the low or high temperature tests, and erratic detection at the high RH condition. Neither VaporTracer unit could be calibrated at 0 °C, and the VaporTracer units showed no response to HD exposures.

In its positive mode, the VaporTracer units consistently demonstrated GA and GB detection response at ambient temperature with no adverse effects from either high or low RH as shown in Tables 3 and 4, respectively. However, the VaporTracer could not be tested at the planned cold temperature of -10 °C because the LCD screen could not be displayed. At 0 °C, the units would not calibrate properly, and no response occurred to either GA or GB exposures. In addition, high temperature operation was not successful for either GA or GB detections. Although the units calibrated properly, there was either no response to either GA or GB, or false alarms for GD and GF when GA was tested at the high temperatures.

The noted recovery times for GA detection were slower than those for GB detection. At GA concentrations >0.02 mg/m³, the units required increasing recovery times from 2 to 21 min at the highest concentration tested (3 mg/m³). Recovery times for GB were much shorter. At GB concentrations <1.0 mg/m³, the VaporTracer units required <41 s to recover. At the highest concentration tested, 3.5 mg/m³, the units demonstrated recovery times between 86-166 s.

Table 2. VaporTracer Responses to HD Vapor Concentrations at Various Conditions

Average Conditions		HD Challenge Concentration		HD Response Value	Response Time (s)
Temperature (°C)	RH (%)	(mg/m ³)	(ppm)		
23	<10	0.14	0.02	121-297	4-10
18-23	49-51	0.02	0.003	NR	NR
		0.07	0.01	114-NR	99- NR
		0.09	0.01	62- NR	17- NR
		0.16	0.02	61-132	9-14
		0.20	0.03	100-208	9-20
		1.60	0.24	218-363	3-8
		2.3	0.35	302-436	4-6
		8.1	1.24	232-343	4-8
		30	4.58	441-1293	4-5
24	>90	0.16	0.02	120- NR	38- NR
		0.22	0.03	55- NR	11- NR
0	0	Unable to calibrate VaporTracer units			
40	50	Up to 1.34	0.22	NR	NR
50	50	Up to 0.9	0.15	NR	NR

Table 3. VaporTracer Responses to GA Vapor Concentrations at Various Conditions

Average Conditions		GA Challenge Concentration		GA Response Value	Response Time (s)
Temperature (°C)	RH (%)	(mg/m ³)	(ppm)		
20	5	0.011	0.002	106-181	43-53
20-24	50	0.003	0.001	108-NR	99-NR
		0.004	0.001	104-215	62-99
		0.01	0.002	120-153	33-46
		0.02	0.003	107-163	29-45
		0.10	0.015	137-488	12-20
		0.40	0.06	925-1300	15-24
		1.50	0.23	233-532	9-17
		3.01	0.45	423-1312	4-8
20	90	0.01	0.001	118-133	28-42
0	<10	Unable to calibrate VaporTracer units			
50	<10	0.88	0.144	NR*	NR

*Units A and B responded with false alarms for GD and GF.

Table 4. VaporTracer Responses to GB Vapor Concentrations at Various Conditions

Average Conditions		GB Challenge Concentration		GB Response Value	Response Time (s)
Temperature (°C)	RH (%)	(mg/m ³)	(ppm)		
22	<10	0.010	0.002	104-240	67-99
21-23	50	0.005	0.001	103-NR	54-NR
		0.009	0.002	100-242	86-101
		0.13	0.02	108-318	8-18
		1.00	0.18	102-400	5-76
		3.50	0.61	914-1475	5
22	88	0.01	0.002	100-125	33-89
0	<10	Unable to calibrate VaporTracer units			
40	50	6.78	1.24	NR	NR
50	48	5.18	0.98	NR	NR

5.3 Field Interference.

The results of the field test interferent exposures are presented in Table 5 as number of alarms per number of trials. A false positive response indicates that the instrument showed agent detection response in the absence of CW agent when challenged with potential interferent substances. Field test conditions were 26-31 °C (79-89 °F) and 53-76% RH, with gentle winds from 3-10 mph. Confidence checks were successfully performed on both units at the start of each day and several times throughout the field test evaluations.

During the field evaluations, Unit A was set to negative (H) mode, and Unit B was set to positive (G) mode. Each unit was tested three times with a 90-s cycle exposure time against the listed interferences when possible. Fewer tests of the doused wood fire and the burning tire smoke were conducted. As shown, the units were tested only two times against the doused fire and only once against the burning tire due to excessive residual effects.

Unit A false alarmed for HD for all trials involving burning wood, burning tire, and doused wood fire interferent smokes. Since the smokes appeared to coat the VaporTracer membranes, they were cleaned after each smoke test. Unit B alarmed for GD and GF against burning cloth, burning wood, AFFF Vapor, and diesel exhaust. Unit B also false alarmed for GB

during exposures to revved gasoline engine exhaust, JP8 Vapor, and burning JP8 smoke. Only one trial with each unit was accomplished for the doused fire smoke, and neither unit alarmed during that exposure. After some of the dirty smokes, both units needed to have the membranes cleaned several times before they could be properly calibrated. The overall alarm rates across all tests were 14 of 60 trials (23%) in G mode and 8 of 60 trials (13%) in H mode.

Post field test responses against HD and GB challenges showed the VaporTracer units to have adverse residual effects from the field tests. Response characteristics were not similar to the pre-field test results. The VaporTracer units would not consistently respond to the agent vapor challenges with similar sensitivity after the field tests. In negative (HD) mode, no response was observed at 10 times the MDL. In positive (G) mode, the units could not be properly calibrated to detect GB after the field tests. Maintenance instructions were followed. The dryer, dopant tubes, and membranes were replaced, but the units remained unusable for nerve agents.

5.4 Laboratory Interference Tests.

The laboratory interference tests were conducted at ambient temperatures (20-22 °C) and approximately 50% RH, using CW agent concentrations above the previously determined MDL. Each test was repeated twice. The HD only responses were approximately equal to the responses for interferent plus HD detections when the interferent did not interfere with CW detection. However, testing completed using HD after the field tests required 2-4 times higher concentrations than the previously determined MDL. Because of the inability to restore the VaporTracer to normal operation after the field test, the laboratory interference tests could not be completed using the positive mode. Therefore, in the presence of potential interferents, neither GA nor GB exposures were completed.

Table 6 presents the results of exposing the VaporTracer instruments to several potential interferents with and without HD agent. If the units showed no response to an interferent, then the units were exposed to CW agent in the interferent's presence. The range of HD responses with corresponding response times is given for agent-only detection response and agent-plus-interferent detection response.

The VaporTracer units did not show a false positive alarm to any of the interferent substances at 1% of saturation. However, the 1% vinegar vapor did prevent the units from detecting HD. The units correctly responded to HD after the vinegar was reduced to the 0.1% saturation level.

Table 5. VaporTracer Field Interference Testing Summary

Interferent	VaporTracer with 90 s Interferent Exposures	
	Unit B in G Mode Alarms/Trials, False Response	Unit A in H Mode Alarms/Trials, False Response
Gasoline Exhaust, Idle	0/3	0/3
Gasoline Exhaust, Revved	2/3, GB	0/3
Diesel Exhaust, Idle	1/3, GD and GF	0/3
Diesel Exhaust, Revved	2/3, GD and GF	0/3
Gasoline Vapor	0/3	0/3
Diesel Vapor	0/3	0/3
JP8 Vapor	2/3, GB	0/3
Kerosene Vapor	0/3	0/3
AFFF (6%) Vapor	3/3, GD and GF	0/3
Clorox (6% Bleach) Vapor	0/3	0/3
Insect Repellent (DEET)	0/3	0/3
HTH (10% calcium hypochlorite) Vapor	0/3	0/3
Burning Gasoline Smoke	0/3	0/3
Burning JP8 Smoke	1/3, GB	0/3
Burning Kerosene Smoke	0/3	0/3
Burning Diesel Smoke	0/3	0/3
Burning Cardboard Smoke	0/3	0/3
Burning Cloth Smoke	2/3, GD and GF	2/3, HD
Burning Wood Fire Smoke	1/3, GD and GF	3/3, HD
Doused Wood Fire Smoke	0/2	2/2, HD
Burning Tire Smoke	0/1	1/1, HD
TOTAL ALARMS/EXPOSURES	14/60	8/60

Table 6. VaporTracer Responses to HD Vapor Concentrations With and Without Interferents at Ambient Temperatures and 50% RH

HD Challenge Concentration		HD Challenge Without Interferent		HD Challenge Plus Interferent		
(mg/m ³)	(ppm)	Response HD	Response Time (s)	Interferent	Response HD	Response Time (s)
0.24	0.04	135	10-16	1% Vinegar	NR	NR
0.24	0.04	111-156	11-17	0.1% Vinegar	103-165	12-19
0.23	0.04	103-128	10-16	1% AFFF	100-135	13-18
0.23	0.04	100-116	10-13	1% Diesel	112-128	10-14
0.21	0.03	111-174	10-19	1% Windex	103-129	9-17
0.25	0.04	103-139	10-15	1% Toluene	114-149	12-15
0.25	0.04	102-174	8-25	1% Spray 9	115-140	9-19
0.25	0.04	100-116	17-28	1% Floor Wax	103-123	14-33
0.24	0.04	104-132*	9-102*	1% Bleach	108-137	24-100
0.43	0.07	104-115	9-24	1% Bleach	108-122	8-61
0.32	0.05	109-401	10-13	1% JP8	107-143	9-15
0.33 up to 0.93	0.05 up to 0.14	107-165*	12-17*	1% Gasoline	100-140	9-33
0.98	0.15	104-166	9-39	1% Gasoline	132-145**	8-9**
1.2	0.18	101-187	8-29	1% Ammonia (25 ppm)	123-188**	8-24**

*Unit A only. Unit B showed NR to HD.

**Unit A only. Unit B showed NR to HD plus interferent.

6. CONCLUSIONS

Conclusions are based solely on the results observed during this testing. Aspects of the detectors other than those described were not investigated.

Civilian first responders and HAZMAT personnel use immediate danger to life or health (IDLH) values to determine levels of protection for selection of personal protective equipment during consequence management of an incident. The minimum detection limit (MDL) of the VaporTracer was either equal to or better than the IDLH and the current Joint Services

Operational Requirement (JSOR) for point sampling detectors for the agents tested at ambient temperatures only. The responses occurred in <20 s. The instruments are sensitive and can detect chemical warfare (CW) agents quickly at ambient temperature. The VaporTracer units were unable to detect HD, GA, or GB at the airborne exposure limit (AEL) concentrations.

The units required manufacturer modifications to the conventional VaporTracer instruments that are currently used for narcotics and explosive detection to enable it to detect some of the CW agents. Humidity effects were alleviated by replacing the dryer cartridges regularly during the evaluation. However, high humidity caused inconsistent HD detection response at the MDL. The units would not operate properly for GA, GB, and HD detection at either the high or low temperature extremes tested.

False alarm rates to tested field interference substances were at 14/60 trials and 8/60 trials for positive and negative modes of operation, respectively. Field interferent testing showed false positive responses to some engine exhausts and smokes, indicating that the instrument might give false CW detection responses during smoky emergency situations when there may not be actual CW agent vapor present. Residues from the field interference testing grossly affected the performance of the instruments. Erratic agent detection performance following the field tests showed that the units had lost sensitivity in the negative mode. Neither unit was functional in the positive mode after the field tests. The units were returned to the manufacturer and required thorough cleaning to restore the instruments for future use.

The controlled laboratory environment tests with potential interferent substance vapors showed no false responses to 1% saturation of the interferents tested in negative (HD) mode. The post field tests' performance precluded completion of the laboratory interference plus agent tests in the positive mode (G agents). The ability to detect HD agent in the presence of a potentially interfering vapor, when the vapor itself does not cause a false alarm, was demonstrated. Only 1% vinegar vapor interference prevented detection of HD. The HD detection response resumed when the vinegar vapor was lowered to the 0.1% level.

The poor performance observed at temperatures' extremes, the frequent maintenance required, and the residual effects from field test exposures, limit the usefulness of the VaporTracer as a warning device.

LITERATURE CITED

1. Longworth, Terri L. et al, Testing of Commercially Available Detectors Against Chemical Warfare Agents: Summary Report, ECBC-TR-033, U.S. Army Edgewood Chemical Biological Center, Aberdeen Proving Ground, MD, May 1999, UNCLASSIFIED Report (AD A364 123).
2. ATCD-N, MEMORANDUM, Subject: Joint Services Operational Requirement (JSOR) for the Automatic Chemical Agent Detector Alarm (ACADA), HQDA, U.S. Army Training and Doctrine Command, Fort Monroe, VA, 3 August 1990.
3. VaporTracer Portable Contraband Detection and Identification System: User's Manual, Ion Track Instruments, Wilmington, MA, 1999.
4. Ong, Kwok Y., Multi-Purpose Chemical Agent Vapor Generation System, ERDEC-TR-424, U.S. Army Edgewood Research, Development and Engineering Center, Aberdeen Proving Ground, MD, July 1997, UNCLASSIFIED Report (AD B227 407).
5. Ong, Kwok Y. et al, Analytical Methodology for Quantitative Determination of O-ethyl-S- (2-Diisopropylaminoethyl) Methylphosphonothiolate (VX), ERDEC-TR-476, U.S. Army Edgewood Research, Development and Engineering Center, Aberdeen Proving Ground, MD, March 1998, UNCLASSIFIED Report (AD A342 871).
6. The Army Chemical Agent Safety Program, Army Regulation 385-61, Department of the Army, Washington, DC, 28 February 1997, UNCLASSIFIED Regulation.